Study Committee C4

PS3 Challenges and Advances in Power System Dynamics

10202 C4

Converter Driven Oscillation in Power Systems with High Penetration of HVDC Interconnectors

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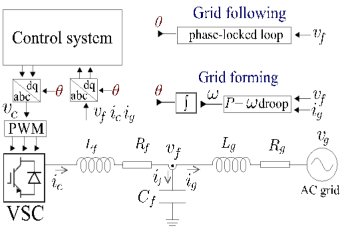
Motivation

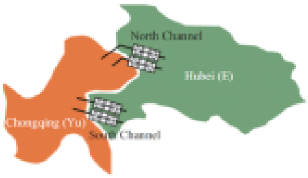
- Power electronic converters in the transmission network has resulted in the increased risk of electrical oscillatory instabilities. E.g. WTGs, HVDC connections, solar PV, FACTs.
- The GB transmission network has multiple HVDC links operating on the South East coast, connecting to the European continent.
- The paper presents insights into both the AC grid and converter stability analysis to explain and identify the mechanisms and causes of these unstable interactions with the power system.

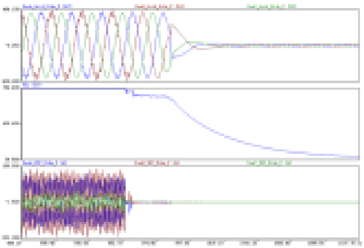
Method/Approach



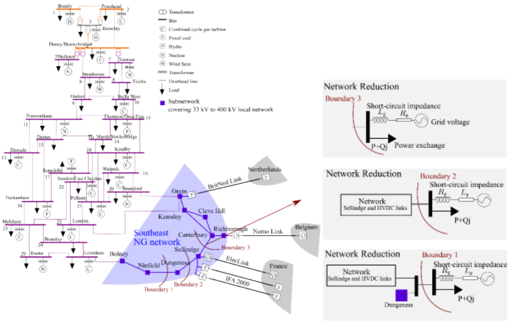
- The stability analysis for the inverter is conducted by using the small-signal stability method and the results are shown as the pole map. A generic small-signal model is developed based on the inverter system shown in figure above, both grid-forming and grid-following controls are included.
- The interaction between the VSC and the AC is mainly focused on the topology in figure above and the parameters of a HVDC link in the south coast of the GB network. How the controls and grid impedance impact the interaction is analysed using small-signal modelling and time-domain simulation.
- To better understand any potential oscillatory instability risk, a more detailed electromagnetic model was established to replicate characteristics and evaluate the sensitivity of potential interactions and oscillations to grid inductance and stiffness, power injection levels and VSC control.

Objects of investigation





- Stability analysis from the grid side: grid stiffness stability analysis, stability analysis for resistance of grid impedance, stability analysis for power exchange.
- Stability analysis from the converter side: VSC Control impact on the interaction, VSC reacts to the various grid impedance, experiences of VSC resonance with the AC gird.



- GB network modelling and reduction: modeling, GB network reduction.

PARIS 2022

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Simulation results

- When SCR<1.2, the grid voltage is very weak, and cannot maintain the connected VSC stable. This demonstrates weak grids introduce undesired oscillations or instability when inverters are connected.
- The inverter loses stability when connecting to a grid with high inductive impedance Zg= 1p.u., but when the grid resistance increases, it improves stability and the inverter returns to stable operation.
- Results indicate increasing the active power injection of the VSC makes the grid connection more vulnerable to instability; Higher reactive power injection may cause instability, which implies reactive power compensation helps stabilize the VSC.
- The designs of the inner current loop are different, and reducing cut-off frequency helps to stabilize the VSC with grid-following control, but conversely, increasing cut-off frequency helps to stabilize the VSC with grid-forming control.
- For a VSC with grid-forming control, the inverter is more stable with high grid impedance (weak grid) However, with grid-forming control, a low grid impedance makes the poles move towards the right-half plane, hence the stability is reduced.
- For a weak grid, the control of the inverter matters to the voltage fluctuation, and improper fast-response tuning could result in an intolerable voltage fluctuation, which leads to instability.

Discussions

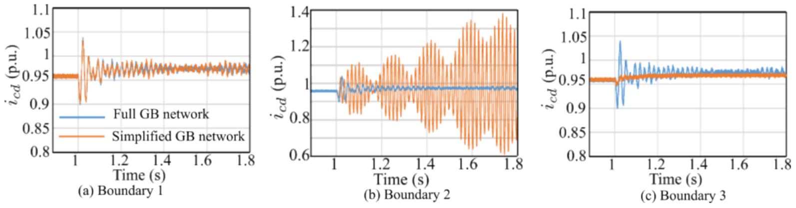
- A grid-connected VSC interacts with the AC grid could cause oscillations or even instability. The reasons include:

System	Instability causes
Grid network	High inductance
	Low grid stiffness
	Low reactive power compensation
	High active power
Grid following control	Weak grid
	Fast response of current control and PLL
Grid forming control	Strong grid
	Slow response of current control

- When conducting network reduction, the causes must be considered to accurately capture the oscillatory interactions between grids and VSCs.

Conclusions

- Network reduction is used to reduce the complexity of the network model to achieve simulation efficiency. However, it needs to be carefully conducted to ensure the oscillatory characteristics of the studied network are correctly captured in the reduced network model.
- The causes of instability between the VSC and the grid include the inductance and stiffness of the grid, the level of power injection and the control approach used by the VSC.
- Based on these instability causes, a reduction exercise has been conducted on the GB network to enhance the efficiency of the simulation study whilst correctly maintaining the dynamics of oscillatory interactions with VSCs.



Simulation studies of the interaction between the a HVDC link and the GB grid

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